

Dynamic Coattention Networks for Question Answering

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- Question Answering
- Related Work

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- Document and Question Encoder
- Coattention Encoder
- Dynamic Pointing Decoder

3 Experiments

- Qualitative Examples
- Results

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- Human annotated high quality but small dataset
- Large scale dataset through semi-annotated techniques but far from natural language
- Stanford Question Answering dataset(SQuAD)
 - Larger than all previous hand-annotated datasets
 - Various qualities
 - Answers are spans in a reference document

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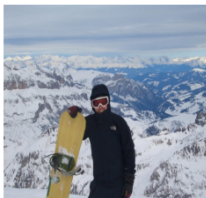
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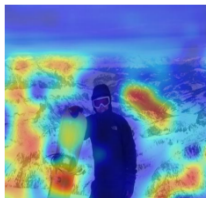
- Statistical QA
 - Rule-based algorithms
 - Linear classifiers over feature sets: lexical features(bag of words), word distance, word order, pos_tag, dependency parse
- Neural QA
 - NLI(natural language inference) : match LSTM encoder + pointer network decoder,
 - dynamic chunk reader: extract answer candidates and rank
 - hierarchical co-attention model



Q: what is the man holding a snowboard on top of a snow covered? A: **mountain**



what is the man holding a snowboard on top of a snow covered



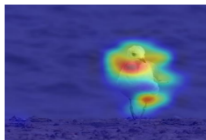
what is the man holding a snowboard on top of a snow covered ?



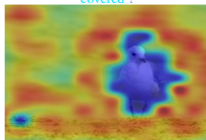
what is the man holding a snowboard on top of a snow covered ?



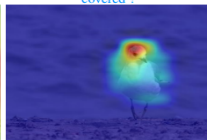
Q: what is the color of the bird? A: **white**



what is the color of the bird ?



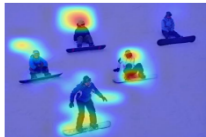
what is the color of the bird ?



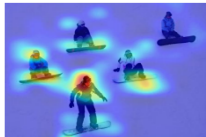
what is the color of the bird ?



Q: how many snowboarders in formation in the snow, four is sitting? A: **5**



how many snowboarders in formation in the snow , four is sitting ?



how many snowboarders in formation in the snow , four is sitting ?



how many snowboarders in formation in the snow , four is sitting ?

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Overview

End-to-end neural network for question answering:

- A coattention encoder captures the interaction between the question and the document
- A dynamic pointing decoder alternates between estimating the start and end of the answer span

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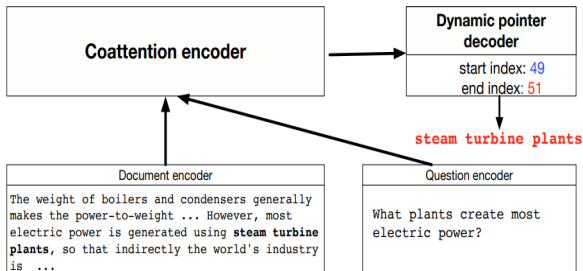


Figure 1: Overview of the Dynamic Coattention Network.

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Document and Question Encoder

- Sequence of word vectors in document:

$$(x_1^D, x_2^D, \dots, x_n^D)$$

$$\Rightarrow d_t = LSTM_{enc}(d_{t-1}, x_t^D)$$

$$\Rightarrow D = [d_1 \dots d_m d_\phi] \in \mathbb{R}^{l \times (m+1)}$$

- Sequence of word vectors in question:

$$(x_1^Q, x_2^Q, \dots, x_m^Q)$$

$$\Rightarrow q_t = LSTM_{enc}(q_{t-1}, x_t^Q)$$

$$\Rightarrow Q' = [q_1 \dots q_n q_\phi] \in \mathbb{R}^{l \times (n+1)}$$

$$\Rightarrow Q = \tanh(W^{(Q)}Q' + b^{(Q)}) \in \mathbb{R}^{l \times (n+1)}$$

(allow for variation between question encoding space and document encoding space)

- d_ϕ and q_ϕ : sentinel vector

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Coattention Encoder

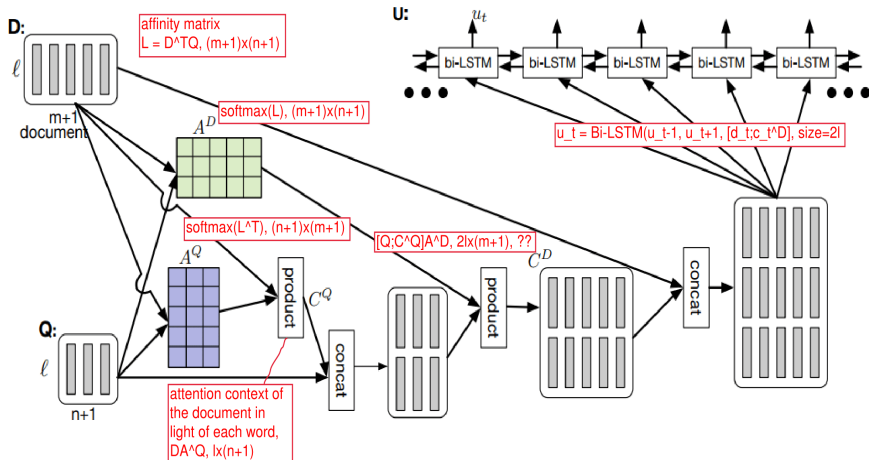


Figure 2: Coattention encoder. The affinity matrix L is not shown here. We instead directly show the normalized attention weights A^D and A^Q .

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Dynamic Pointing Decoder

$h_i = LSTM_{dec}(h_{i-1}, [u_{s_{i-1}}; u_{e_{i-1}}])$, $U = [u_1, \dots, u_m] \in \mathbb{R}^{2l \times m}$ from encoder

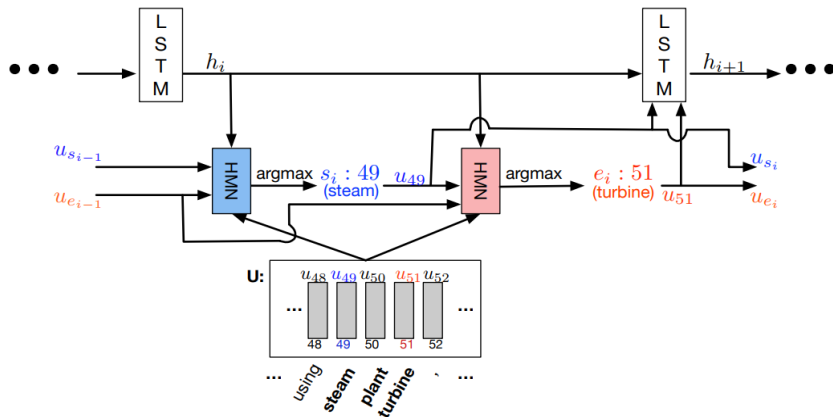


Figure 3: Dynamic Decoder. Blue denotes the variables and functions related to estimating the start position whereas red denotes the variables and functions related to estimating the end position.

Dynamic Pointing Decoder

$$h_i = LSTM_{dec}(h_{i-1}, [u_{s_{i-1}}; u_{e_{i-1}}])$$

Given current hidden state h_i , previous start position $u_{s_{i-1}}$ and previous end position $u_{e_{i-1}}$, how to estimate the current start position s_i and current end position e_i ?

$$s_i = \operatorname{argmax}(\alpha_1, \dots, \alpha_m)$$

$$\alpha_t = \mathbf{HMN}_{start}(u_t, h_i, u_{s_{i-1}}, u_{e_{i-1}})$$

Highway Maxout Network(HMN)

$$HMN(u_t, h_i, u_{s_{i-1}}, u_{e_{i-1}}) = \max(W^{(3)}[m_t^{(1)}; m_t^{(2)}] + b^{(3)}) \quad (1)$$

$$r = \tanh(W^{(D)}[h_i; u_{s_{i-1}}; u_{e_{i-1}}]) \quad (2)$$

$$m_t^{(1)} = \max(W^{(1)}[u_t; r] + b^{(1)}) \quad (3)$$

$$m_t^{(2)} = \max(W^{(2)}m_t^{(1)} + b^{(2)}) \quad (4)$$

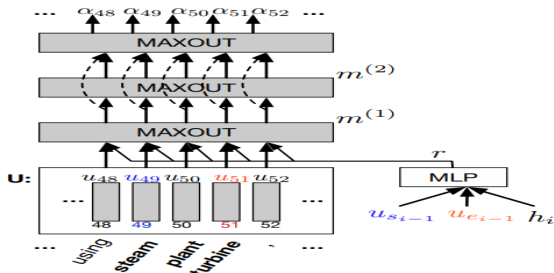


Figure 4: Highway Maxout Network. Dotted lines denote highway connections.

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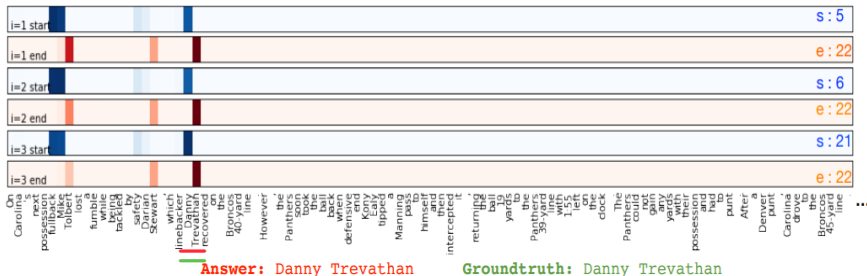
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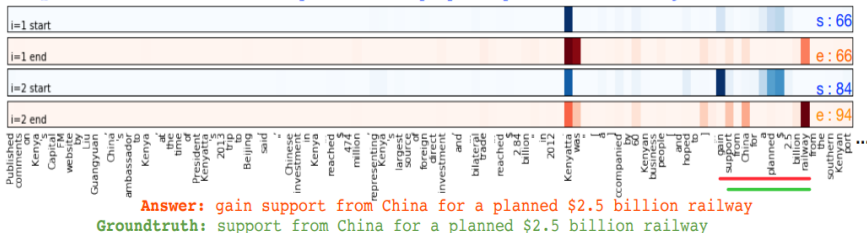
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Qualitative Examples

Question 1: Who recovered Tolbert's fumble?



Question 2: What did the Kenyan business people hope for when meeting with the Chinese?



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Results

Model	Dev EM	Dev F1	Test EM	Test F1
<i>Ensemble</i>				
DCN (Ours)	70.3	79.4	71.2	80.4
Microsoft Research Asia *	—	—	69.4	78.3
Allen Institute *	69.2	77.8	69.9	78.1
Singapore Management University *	67.6	76.8	67.9	77.0
Google NYC *	68.2	76.7	—	—
<i>Single model</i>				
DCN (Ours)	65.4	75.6	66.2	75.9
Microsoft Research Asia *	65.9	75.2	65.5	75.0
Google NYC *	66.4	74.9	—	—
Singapore Management University *	—	—	64.7	73.7
Carnegie Mellon University *	—	—	62.5	73.3
Dynamic Chunk Reader (Yu et al., 2016)	62.5	71.2	62.5	71.0
Match-LSTM (Wang & Jiang, 2016b)	59.1	70.0	59.5	70.3
Baseline (Rajpurkar et al., 2016)	40.0	51.0	40.4	51.0
Human (Rajpurkar et al., 2016)	81.4	91.0	82.3	91.2

Table 1: Leaderboard performance at the time of writing (Nov 4 2016). * indicates that the model used for submission is unpublished. — indicates that the development scores were not publicly available at the time of writing.

Model	Dev EM	Dev F1
<i>Dynamic Coattention Network (DCN)</i>		
pool size 16 HMN	65.4	75.6
pool size 8 HMN	64.4	74.9
pool size 4 HMN	65.2	75.2
DCN with 2-layer MLP instead of HMN	63.8	74.4
DCN with single iteration decoder	63.7	74.0
DCN with Wang & Jiang (2016b) attention	63.7	73.7

Table 2: Single model ablations on the development set.

Summary

- An end-to-end neural network architecture for question answering
- On the SQuAD dataset achieves the state of the art results at 75.9% F1 with a single model and 80.4% F1 with an ensemble.